Vegetation and Habitat Conservation – a Strategic Framework

Victor A Sposito

Summary of

Actions Towards Sustainable Outcomes

Environmental Issues/Principal Impacts

The 'Vegetation and Habitat Strategic Framework' and the 'Regional Habitat Significance Model' can be used by State and Local Governments, regional organisations, land use and environmental planners, landscape architects and other stakeholders to appraise the extent and quality of native vegetation and identify significant habitats at strategic and local levels. Aspects to consider include the following.

- Protection and enhancement of native vegetation and habitat according to Ecological Sustainable Development objectives.
- Vegetation and habitat are essential elements of the complex natural environment.
- Vegetation provides habitat for fauna species and underpins the function of ecosystems.
- These biological assets are difficult or impossible to replace once they are lost or degraded.
- Greatest conflict between physical/economic development and biodiversity conservation exist in all peri-urban, regions (or fringe of cities) of Australia.
- Multiple criteria assessment of native vegetation and habitat significance within an Ecologically Sustainable Development framework.
- Crucial input into the planning and design of all new residential, industrial and infrastructural developments within an Ecologically Sustainable Development framework.

Basic Strategies

In many design situations, boundaries and constraints limit the application of cutting EDGe actions. In these circumstances, designers should at least consider the following:

- Aim to protect biological diversity and maintenance of essential ecological processes and life support systems.
- Make an inventory of key vegetation and habitat in all new developments.
- Ensure participation of stakeholders in the assessment and prioritisation process.

Cutting EDGe Strategies

- Apply the Analytic Hierarchy Process, which is a general method of assisting decision-making based on the integration of scientific and expert/stakeholder knowledge and/or experience of the situation.
- Use the above method in combination with a Geographic Information System, which employs powerful computer-based tools and procedures to handle spatial data.
- Ensure there is systematic collection and retrieval of relevant information as part of a GIS-based decision support system.
- Set priorities for further investigative work on vegetation and habitat at both strategic and operational (detail) levels of planning.

Synergies and References

- BDP *Environment Design Guide*: Gen 3, Gen 17, Gen 37, Gen 39, Tec 15, Des 15, Des 50
- Bureau of Rural Sciences, 2002, *Land Use Mapping at Catchment Scale – Principles, Procedures and Definitions*, DEST, Canberra, http://www. affa.gov.au
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- Saaty, T, 1995, *Decision Making for World Leaders: The Analytic Hierarchy Process for Making Decisions in a Complex World,* RWS Publications, Pittsburgh
- Yamada, K, et al, 2003, *Eliciting and integrating expert knowledge for wildlife habitat modelling*, 'Ecological Modelling', 165, pp 251–264

ENVIRONMENT DESIGN GUIDE

Vegetation and Habitat Conservation – a Strategic Framework

Victor A Sposito

This note outlines a framework to appraise the extent and quality of native vegetation, and identify significant habitats at strategic regional and local levels, namely a Vegetation and Habitat Strategic Framework. *The cornerstone of the framework is the formulation of a 'Regional Habitat Significance Model' which is built through the integration of the analytic hierarchy process (AHP) and a geographic information system (GIS). The GIS platform enables the ongoing improvement and input of relevant information and the preparation of a new assessment in an adaptive, cyclical planning process.*

State and Local Governments, regional organisations, land use and environmental planners, landscape architects and other stakeholders can use the framework and its model as an important strategic planning tool. Significant areas of habitat can be initially identified through the framework. Planning and investment strategies can then be put into place to conduct target investigations and/or preserve habitats and enhance the environment.

1.0 Introduction

The Australian continent is distinguished by its size, age and geological characteristics, as well as by its relative evolutionary isolation for at least the past 50 million years. This has resulted in a rich diversity of unique life forms. Many of them are found nowhere else (that is, they are 'endemic') – over 80% of mammals, reptiles, flowering plants, fungi, molluscs and insect species in Australia are endemic (State of the Environment Advisory Council, 1996; Commonwealth of Australia, 1997).

Australian native vegetation includes all vegetation that naturally occurs in the continent and has not been introduced by humans from other parts of the world. Native vegetation has big impacts on many sectors of the community's activities including agriculture, forestry, fisheries and tourism. The extent of native vegetation throughout Australia has been dramatically reduced since European settlement, mainly though urbanisation and land clearing for agriculture and forestry plantations. For instance, approximately 66% of Victoria's native vegetation has been cleared since the 1750s. Nevertheless, the existing native vegetation of the state is very rich and complex; there are some 3,221 native plant species, of which 1,479 are threatened in various forms (Victorian State Government, Department of Natural Resources and the Environment, 2002).

The protection and enhancement of high quality native vegetation is very important, as once these biological assets are degraded or lost it is often difficult or impossible to replace them. Generally, vegetation which is considered of high quality contains all the species that are typically associated with the particular vegetation type in a particular geographic area, has few, if any, weeds, and shows few signs of human disturbance. In efforts to conserve biological diversity (or biodiversity), the protection and enhancement of vegetation is considered a priority, as vegetation provides habitat for fauna species and underpins the function of ecosystems (Crown – State of Victoria, 1997).

A common problem confronted by most authorities in charge of preserving native vegetation and habitat is that there is usually insufficient information to determine which are the important areas to conserve and/or concentrate investment for detailed investigations to improve knowledge on those essential assets. Australian governments are developing and seeking methods for biodiversity assessment that can be used for those purposes (Australia and New Zealand Environment and Conservation Council or ANZECC, 2000). Several habitat models have been developed to assist vegetation and habitat managers, though most of them have been developed and applied at a very local (i.e. less than 20 hectares) or site specific levels (United States Fisheries and Wildlife Services or USFWS, 1996; Burgman et al, 2001) – two of them will be referred to in Section 6, below.

In this context, this note outlines a framework, *Vegetation and Habitat Strategic Framework*, to appraise the extent and quality of native vegetation, and identify significant habitats at strategic regional and local government levels in Australia. Primary Industries Research Victoria (PIRVic) – Landscape Systems Science, in collaboration with the Arthur Rylah Institute of the Victorian Department of Sustainability and Environment (DSE), developed the strategic approach. The methodology is explained by reference to its application in the Shire of Macedon Ranges in Victoria (Department of Primary Industries, 2004b)[1].

2.0 Ecologically Sustainable Development

The framework is formulated from the standpoint of Ecologically Sustainable Development (ESD) as a decision support system in a geographic information system (GIS) platform (see BDP *Environment Design Guide:* Tec 15, 'GIS and Remote Sensing'). The GIS allows developing spatially-explicit information and thus enables habitat and natural resource managers

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[1] Macedon Ranges is located in Regional Victoria between Melbourne and the Regional Centre of Bendigo, about 70 kilometres from Melbourne's CBD. It is predominantly rural in character with some established urban and town/villages centres such Romsey, Kyneton, Woodend and Gisborne. It is part of the extensive peri-urban region surrounding the built-up areas of Melbourne. Its population was 37,672 in 2001; it is now growing at over 1,000 people per year, and it is forecast to be about 55,000 by 2031.

to examine spatial distributions of species and their environment. Moreover, the GIS platform allows the ongoing improvement of the framework through the input of new and/or better information and the preparation of a new assessment in an adaptive, cyclical planning process.

Several BDP *Environment Design Guide* notes have introduced various definitions of ESD. For the purpose of this note, the definition derived from the *National Strategy for Ecologically Sustainable Development* (Council of Australian Governments, 1992) is adopted: *'development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends'.* The three core objectives are:

- To enhance individual and community well being by following a path of economic development that safeguards the welfare of future generations (economic field).
- To provide for equity within and between generations (or intra- and inter-generational equity) (social field).
- To protect biological diversity and maintain essential ecological process and life-support systems (biophysical field).

Given its main purpose, the primary focus of the framework is on the third core objective of ESD.

3.0 Vegetation and Habitat Strategic Framework

3.1 Planning Process

The planning process includes seven stages as shown in Figure 1; this should not be confused with the framework, which is built through the planning process. The planning process depicted in this figure is an applied version, developed by the author of this note, of the generic model of the rational decision-making process (see, for instance, Chadwick, 1971; Sposito, 2005). In the figure, the tasks, or activities, have been set up as part of a cyclical process; work at each stage leads to the next in progression towards implementation. This is, however, a convenient simplification as it will be often desirable to reiterate the activities at various stages in the light of what has been learned and/or when new information becomes available. For instance, monitoring feeds back into various stages, including model construction and priority setting. A brief description of the key stages is provided in the following sub-sections.

The whole process is informed by the 'Policy Context', which is depicted in the left of the figure, and by stakeholders and community consultation. The Policy Context includes the relevant international, national and state policy documents that have a bearing on studies of this nature.

For instance, in Victoria they include: the Ramsar Convention (1971) for the protection of wetlands of international importance; and the Bilateral Agreements with China – China/Australia Migratory Birds

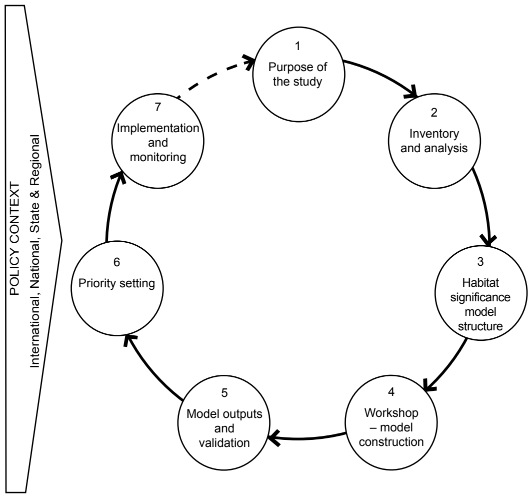

Figure 1. Planning Process

Agreement (CAMBA, 1996) and Japan – JAMBA (1974) for the protection of migratory birds and their environments. The *National Strategy for Ecologically Sustainable Development* (COAG, 1992), the *National Strategy for the Conservation of Australia's Biological Diversity* (Commonwealth of Australia, 1997), and the national *Environment and Protection Act 1999* are especially significant because they tie the actions of the Commonwealth and State Governments to pursue ESD, and identify, conserve and manage Australia's biodiversity (see also Section 3.3, below). At state government level, the most important documents are the *Flora and Fauna Guarantee Act 1988*, the *Planning and Environment Act 1987*, the *Catchment and Land Protection Act 1994*, *Victoria's Biodiversity Strategy* (Crown – State of Victoria, 1997), and *Victoria's Native Vegetation Management – A Framework for Action* (Department of Sustainability and Environment, 2002*).* The latter focuses on native vegetation management and addresses the strategic issues of protection, enhancement and revegetation across the state. The two main concepts outlined in this framework are the goal of 'Net Gain' and the importance of not only quantity of native vegetation, but also quality. Gain is to be achieved by ensuring that the overall losses of native vegetation are less than the overall gains, as well as restricting individual losses of native vegetation whenever possible (see also Section 6.2, below).

3.2 Purpose of the Study – Stage 1

The aim of the study should be clearly stated from the outset of the planning process – this corresponds to stage 1 in Figure 1. In the case of Macedon Ranges, the study objectives were the following:

1. To improve the information and knowledge on the environmental characteristics of the Macedon Ranges Shire, particularly in relation to the vegetation extent, type and quality.
2. To formulate a Vegetation and Habitat Strategic Framework as a decision-support system that is easily transferable to the Macedon Ranges Shire Council's GIS platform.

3. To appraise the habitat value of the study area to help establish priorities for conservation and further investigation by the Macedon Ranges Shire Council.

3.3 Inventory and Analysis – Stage 2

Stage 2 of the planning process focuses on the biological assets that are considered a priority for conservation, such as native vegetation, rare and threatened flora and fauna, inland waters (wetlands and rivers), and biologically significant sites; and features that provide information on the existing land uses. Because spatial context is critical for building habitat models, the key information obtained or developed was recorded in map and tabular forms as components of the GIS-based decision support system. In the study, multi-scale data layers were used at as high a resolution as possible (between 1:5,000 to 1:25,000 geographic scales). A brief description of the main components of the GIS-based framework follows.

Native Vegetation – Ecological Vegetation Classes

As mentioned, Australian native vegetation includes all plants that naturally exist in the continent and have not been introduced by humans from other parts of the world.

'Ecological Vegetation Classes' (EVCs) are the basic units used for mapping biodiversity and conservation assessment at landscape, catchment and broader scales in Victoria (DNRE, 2002). They are based on the types of plant communities (including species and structural information), ecological information relevant to the species that comprise the communities (including life-form and reproduction), and information about variations in the physical environment (including climate, geology and soils, aspect. elevation, landform and salinity). Each EVC represents one or more plant (floristic) communities that occur in similar types of environments and respond to environmental events, such as bushfires, in similar ways. The conservation status of the EVCs is established on each Australian bioregion, ranging from 'depleted', to 'least concern' (Crown – State of Victoria, 1997). A description of the EVCs in Victoria can be seen in Commonwealth of Australia and Victoria RFA Steering Committee report (2000).

Rare or Threatened Fauna and Species

In order to qualify for a rare or threatened category, a *taxon*[2] must meet the criteria established either at national or state level. At the national level, the *Environment Protection and Biodiversity Conservation Act 1999* is a major consolidation of Commonwealth legislation dealing with biodiversity and is the only Act that protects biodiversity on private land. In Chapter 5, Part 13 – Species and Communities (Division 1 of the Act), the criteria for listing threatened or rare fauna species – Australian Rare or Threatened Species (AROTS) – is set up. Maps indicating the location of the AROTS across the various Australian bioregions are being progressively prepared.

In Victoria, the *Flora and Fauna Guarantee Act 1988* provides for the listing of taxa (genera, species, subspecies and varieties) and ecological communities and of flora and fauna. This Act does not, however, apply to private land. Under this Act, *Action Statements* are prepared that provide background information about the species (including description, distribution and habitat) and the threats which affect them.

Land Use – Australian Land Use and Management (ALUM) Classification

Land uses have a major impact on Australia's natural resources and environment through their effects on water, soils, nutrients, plants and animals.

Land use mapping in Australia is based on the ALUM Classification that orders land uses in a systematic and logically consistent way. The classification has a three-level hierarchical structure with primary, secondary and tertiary classes broadly organised in terms of the potential degree of modification and impact on a supposed 'natural state' (essentially unmodified native land cover). The following six list groupings are used:

1. Conservation and natural environments
2. Production from relatively natural environments
3. Production from dryland agriculture and plantations
4. Production from irrigated agriculture and plantations
5. Intensive uses
6. Water

(Bureau of Rural Sciences, 2002)

The Bureau of Rural Sciences, in association with the National Land and Water Resources Audit and the states, is undertaking a major program to map the whole continent, at various geographic scales ranging from 1:25,000 to 1:250,000, using the ALUM Classification. The following websites provide information on this program: http://www.affa.gov.au (follow the links to Landscape Management Sciences, Land Use and Land Management Practice Mapping for Australia), and National Land and Water Resources Audit – http://www.nlwra.gov.au.

Map 1 shows the application of the ALUM Classification to Macedon Ranges; for illustration purposes, only land uses to the primary level of the ALUM Classification hierarchy are shown.

[2] The word 'species' has two distinct meanings. As a *biological species concept*, species is defined as a group of organisms that breeds internally but is reproductively isolated from other groups. The second meaning is just one of the end points along the base of the taxonomic pyramid, the ultimate unit of classification of a group of organisms regardless of whether or not they are capable of mating with other organisms. That is, species is a taxon, a unit of classification (Atkins, 2003, p 10).

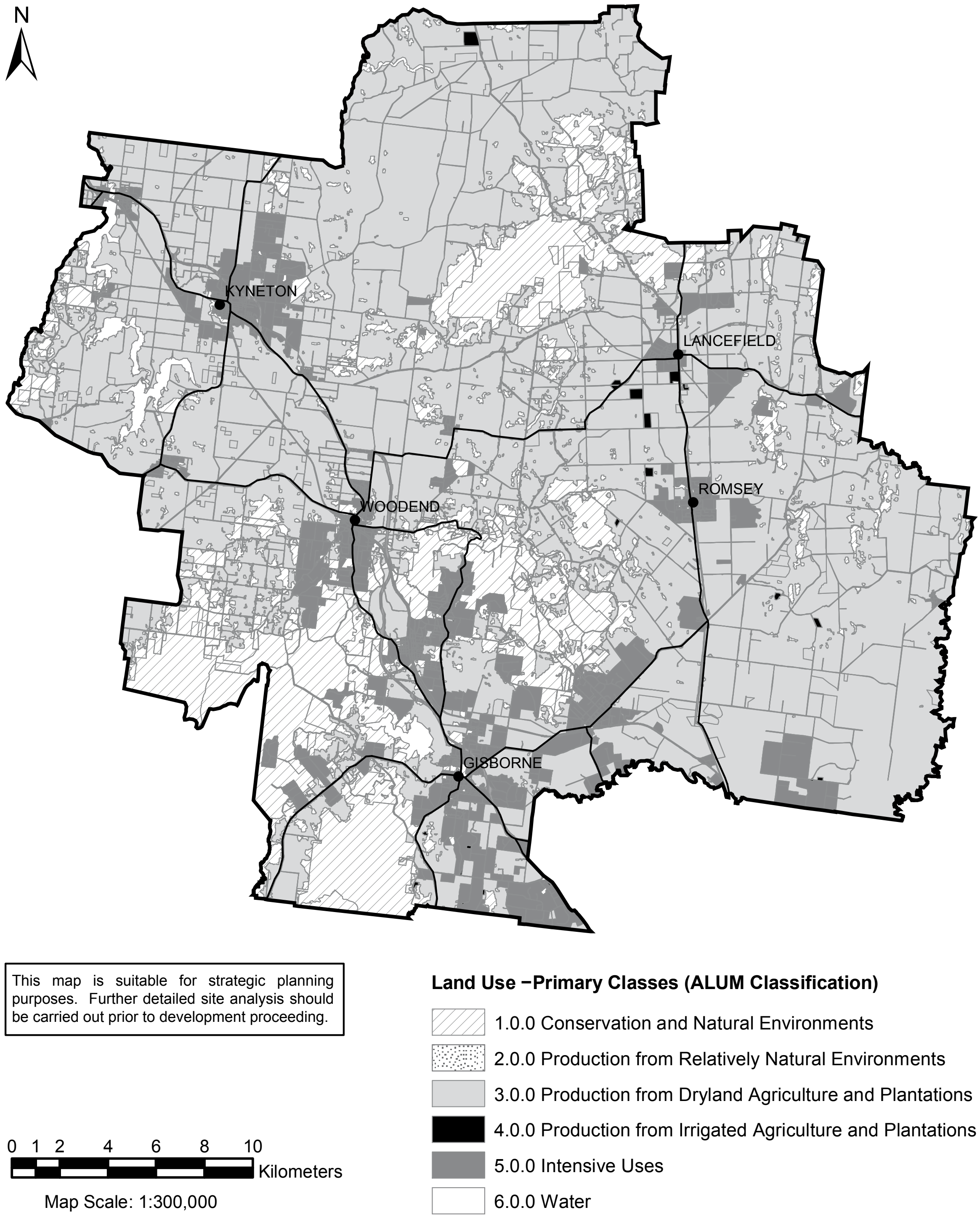

Figure 2. Land Use – Macedon Ranges Shire Council

Wetlands and Rivers

The long history of subsidence and uplift, volcanic activity, erosion and deposition in Australia have produced a rich variety or inland and estuarine aquatic environments (Douglas, 1982). Each environment provides habitat for a variety of plants and animals.

Wetlands are areas of land that are flooded naturally; they are inundated or waterlogged on a permanent, seasonal or intermittent basis. Wetlands include marshes, ponds, lakes, billabongs, meadows and swamps. Australia has a wide variety of wetlands, many of which have unique features and are of high ecological value. Numerous birds, fish, amphibious and other aquatic species depend on wetlands for their survival (State of Environment Advisory Council, SOEAC, 1996, p 7–26).

Waterways comprise several elements including the waterway or watercourses (the river or stream itself), riparian land as well as escarpments and surrounding land. Riparian land extends from the river or stream to the edge of the 'wetted zone'. This includes the stream bank, regularly flooded gullies, wetlands and billabongs located in the floodplain, often defined as the area subject to 1:100 year flood. Maps of rivers, wetlands and flooded areas are generally available in most Australian regions.

3.4 Regional Habitat Significance Model – Structure/ Initial Construction – Stage 3

The cornerstone of the framework is the formulation of a 'Regional Habitat Significance Model', which corresponds to Stage 3 in the planing process. The model is built through the integration of a multiple criteria analysis method with a GIS. Multiple criteria analysis is used for investigating, analysing and resolving decision problems constrained by multiple objectives and criteria (Nijkamp et al, 1990; Voogd, 1983). In its basic form, a multi-criteria analysis model comprises a set of evaluative criteria, a set of weights indicating the importance of those criteria, a set of alternatives, and a set of performance measures indicating the performance of each alternative against each criterion. It has been demonstrated that the integrative approach allows the full potential of both the multi-criteria analysis and GIS as evaluation and decision-making tools (Carver, 1991; Jankowski, 1995).

The *Analytic Hierarchy Process* (AHP) is the multi-criteria analysis method employed in the construction of the Regional Habitat Significance Model; it ranks critical factors in a hierarchy (decision tree) of importance (Saaty, 1995 and 2000). The method has the ability to handle quantitative attributes and the versatility to mix quantitative and qualitative elements (Wedley, 1990). The AHP has been used extensively around the world in multiple applications in various fields ranging from economics to management. It is increasingly being used in environmental decision-making (Varis, 1989; Ramanathan, 2001). In particular, the R&D Division of the Victorian Department of Primary Industries (previously the Department of Natural Resources and Environment – DNRE) has extensively employed the method in land suitability analysis (described in BDP *Environment Design Guide:* Gen 37 – Land Resource Assessment) and it is now being developed to investigate the biophysical impacts of climate change (DPI, 2004c).

The combination of AHP and GIS thus improves the reliability of spatial mapping because not all factors (or layers of information) have equal value in determining the significance of vegetation and habitat across a region. The layers can be weighted accordingly, as will be seen below.

Thomas Saaty, the creator of the analytic hierarchy process, explains that 'basically, the AHP is a method of breaking down a complex unstructured situation into its component parts; arranging these parts or variables into a hierarchical order; assigning numerical values to subjective judgements based on the relative importance of each variable; and synthesising the judgements to determine which variables have the highest priority and should be acted upon to influence the outcome of the situation' (Saaty, 1995, p 5).

In this respect, the AHP incorporates both the qualitative and quantitative aspects of human thought. The former is used to define the problem and its hierarchy, whilst the latter expresses judgements and preferences concisely. The process itself is designed to integrate these two dual properties (Saaty, 1995, p 18). Therefore, the AHP is also an expert-based modelling approach because it relies on the input of experts. See Section 3.4, Expert Workshop – Final Model Construction – Stage 4. Comments in relation to the integration of expert knowledge for habitat modelling will be made in Section 5, below.

The procedure to carry out AHP is the same for all situations, although certain steps may be given special emphasis depending on the issue of interest. The following steps are used in the methodology being described:

1. *Define the issue(s) (problems or opportunities) of interest.*
2. *Identify the focus*. This forms the pinnacle of the hierarchy (constructed in Step 4) and is the outcome being sought from the application of AHP.
3. *Identify the criteria*. Criteria in the form of 'critical factors' are based on research and information, and agreed upon by experts (see the next sub-section).
4. *Construct the hierarchy*. The hierarchy is structured in the form of a decision tree with the overall objective, or focus, at the top. The hierarchy enables the assessment of the impact of higher-order elements on those of a lower level or, alternatively, the contribution of elements in the lower levels to the importance or fulfilment of the elements in the level above.
5. *Assign intensity ratings* to the range of data for the critical factors that have been identified.
6. *Weight the criteria* by posing a set of questions between pairs of criterion at each level of the hierarchy to establish the relative importance or priority. This is carried out through a pair wise comparison – a robust technique for capturing preferences as the user compares all factors against each other but only two factors at a time, and thus can make a more reliable judgement.
7. *Check the consistency of the evaluation*. The consistency ratio of the hierarchy should be 10 per cent or less. If it is higher, a reiteration is necessary by revising the assumptions made in answering the pair wise comparisons.
8. *Finalise weights*. They are completed once the consistency ratio is acceptable.
9. *Integrate the hierarchy and weighted information with mapped data to form a single, composite index of evaluation*.

In the AHP application to construct the Regional Habitat Significance Model, the GIS IDRISI computer software developed by Clark University (USA) is deployed. The linking of the AHP decision-making framework to a GIS platform requires interfacing the

GIS IDRISI software with the *ArcView* Model Builder software module. The resultant (composite) map is obtained from processing all the map overlays, by reclassifying field values to AHP rankings, multiplying each by the associated weight, and afterwards combining the maps together for each level of the hierarchy.[3]

The initial phase in the formulation of the Regional Habitat Significance Model is the construction of the hierarchy (step 4 in the Saaty's process, above). The following specific aspects are incorporated in this phase:

- The hierarchy (decision tree) comprises categories, components and data.
- Categories are the main groups of features included in the model; they are *biological assets, waterways*, and *land use*.
- Components are the individual features included in the model, such as native vegetation (EVCs), fauna and flora species' locations, waterways, biosites, etc.
- Data is listed under each component.

Categories and components in the model are then weighted. Weightings are assigned through consensus of the panel of experts in the next stage of the planning process.

3.5 Expert Workshop – Final Model Construction – Stage 4

An expert workshop is an integral part of model construction – stage 4 in the planning process in Figure 1. The experts should include environmental and land use scientists, planners and landscape architects with good knowledge of vegetation, biodiversity and habitat matters, as well as experts and decision-makers with excellent knowledge of the study area. Usually, a group of 10 to 15 persons is required.

Experts are provided with all the data sets generated in stage 2, *Inventory and Analysis*, of the planning process. The limitations and advantages/disadvantages of each data set are thoroughly discussed. The initial construction of the model (undertaken in stage 3) is validated or modified, and then categories and components are weighted through consensus of the experts.

- Weightings give an indication of the influence that a category has on the overall significance of the study area.
- Weightings are given on a numerical scale (0 to 1), with the lowest value (0) having no influence, and the highest value (1) having a total influence on the area's habitat significance.
- Data is rated on a scale of 1 to 10 because it is the same scale used by the *ArcView* Model Builder (see above). A score of –1 indicates a very significant feature, such as remnant EVC, which must be preserved. Scores of 0–10 provide an indication of the significance of each feature in terms of habitat, with 10 being highly significant and 0 being of only slight significance or having no significance at all.

Figure 3 shows the hierarchy developed for the Habitat Significance Model for Macedon Ranges. Note that factors at each level of the decision-tree's branches add to a total of one.

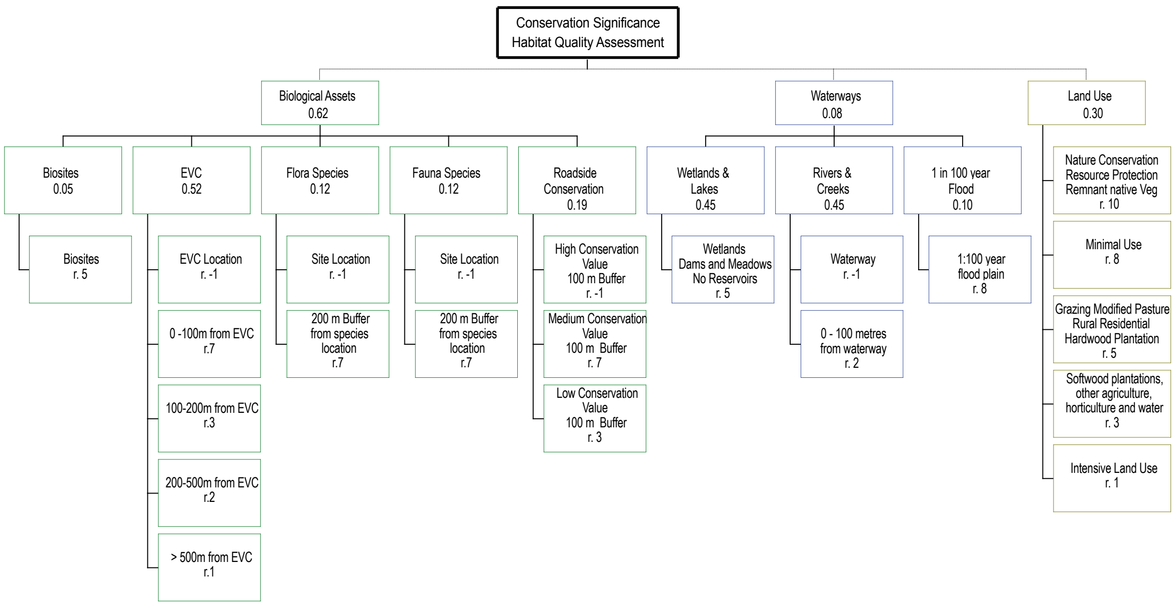

Figure 3. Hierarchy of the Regional Habitat Significance Model

[3] IDRISI is a trademark of Clark University, whilst *ArcView* and Spatial Analyst are trademarks of ESRI Inc. The computer program that integrates all operations and produces the maps has been developed by PIRVic, and can be obtained from the author of this note at: email: victor.sposito@dpi.vi c.gov.au

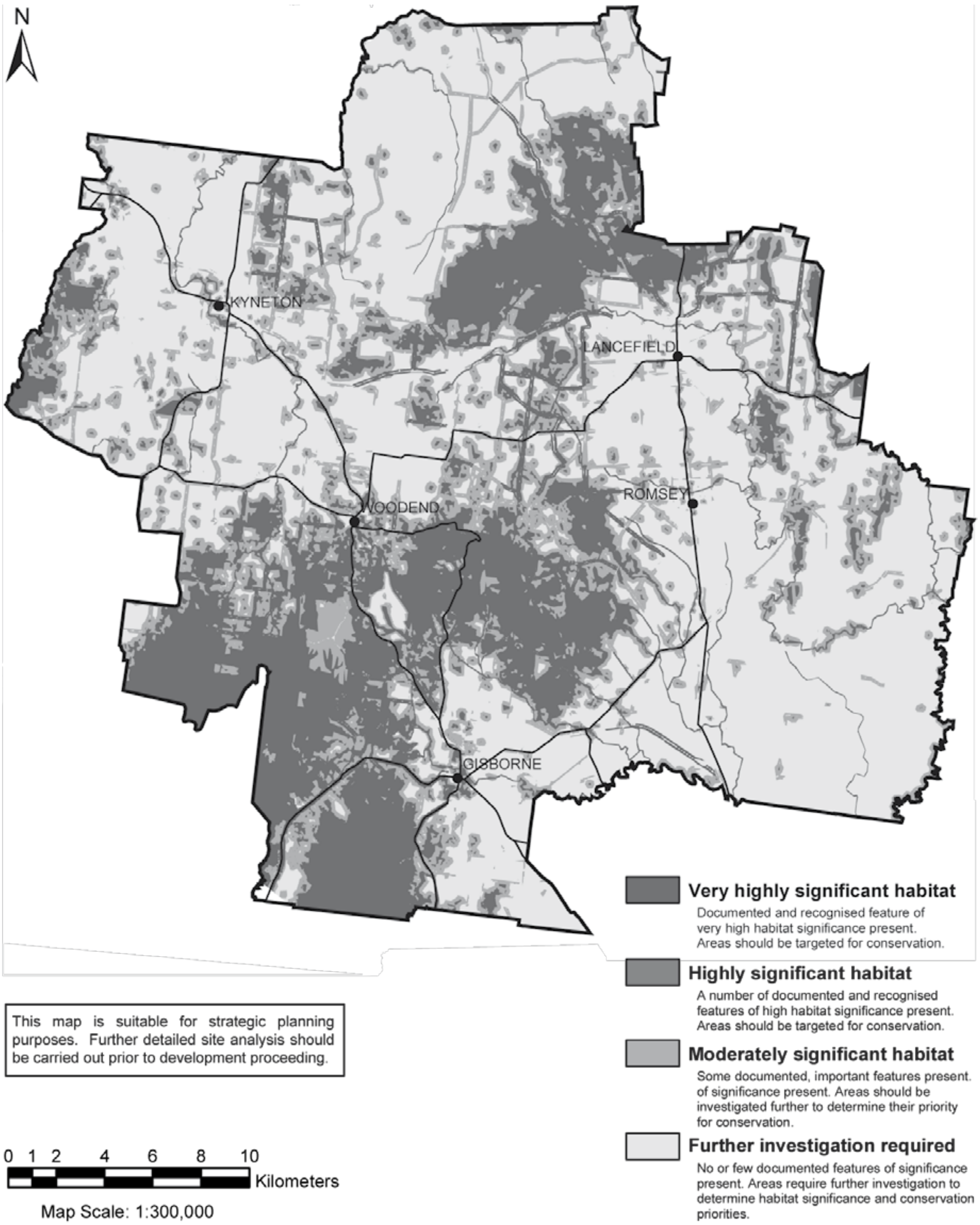

Figure 4. Habitat Significance – Macedon Ranges Shire Council

3.6 Model Outputs and Validation – Stage 5

The computer program developed by Primary Industries Research Victoria creates maps and data tables for every calculation in the model, allowing the users to investigate areas individually, if more information is required at each stage. The model can also be easily adjusted if new data is required or becomes available, or different weightings are needed.

Figure 4 shows the main output of the model for the Macedon Ranges Shire. Four categories of habitat are displayed ranging from 'very highly significant habitat' to areas where 'further investigation is required'. It can be seen that moderately significant habitat generally surrounds the areas of very high significance. This indicates that surrounding areas to significant native vegetation, or important habitat areas, are also endowed with some habitat value and can appropriately act as buffers to surrounding, threatening land uses.

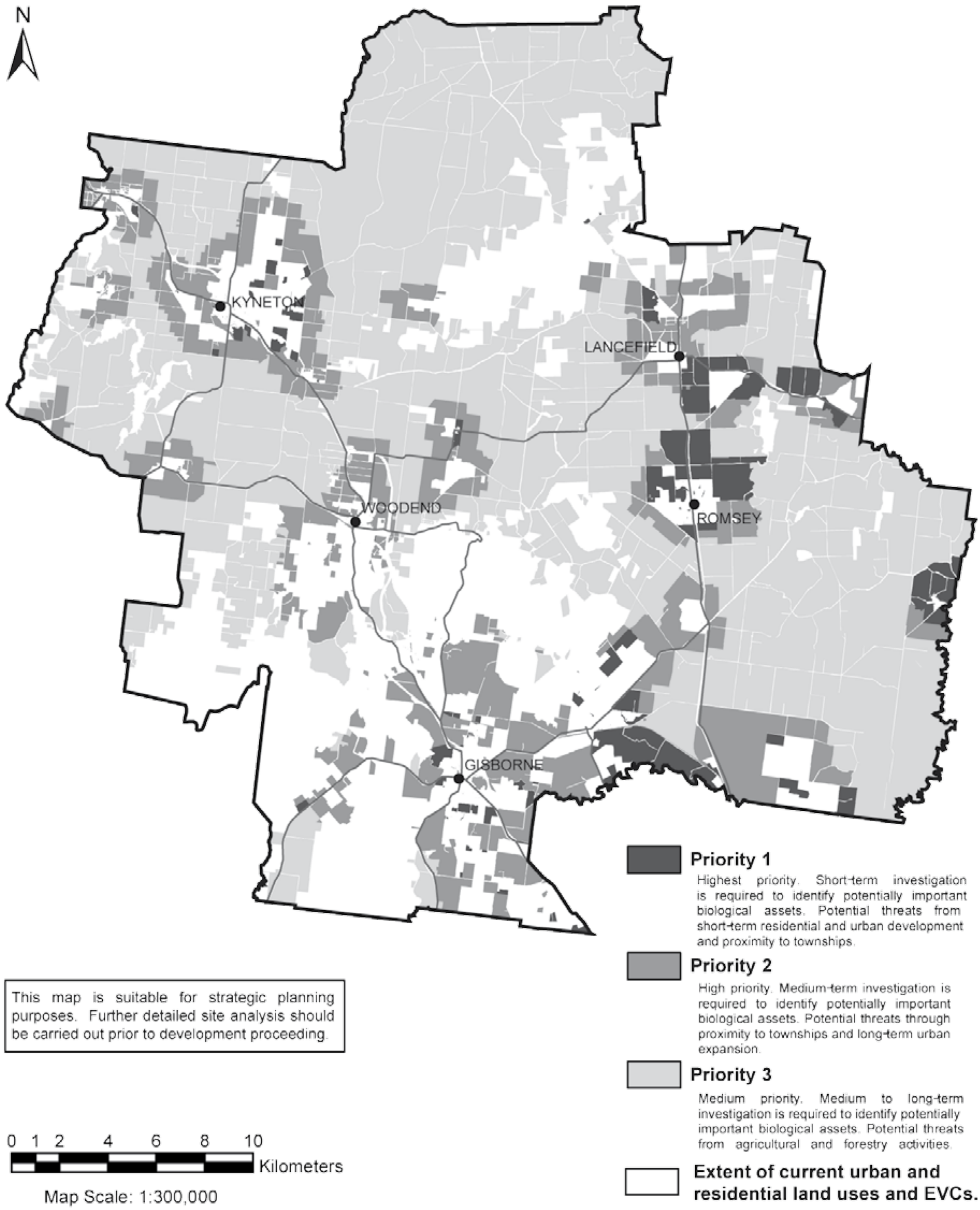

Figure 5. Priority Areas for Further Investigation – Macedon Ranges Shire Council

The validation of the resulting map can take place in a complementary workshop with the same group of experts who participated in the construction of the model for the study area. Because of its computerised nature, the new model output can be run in real-time during the workshop, and again modified if required.

4.0 Priorities for Further Investigation

4.1 Priority Areas – Stage 6

As would happen in most cases, there are extensive areas in the Macedon Ranges Shire where no appropriate data exists. Because of the high costs of detailed mapping of vegetation and habitats, the investigation of those areas needs to be prioritised and a program for sequentially undertaking the investigations in forthcoming years must be established. This is stage 6 in the planning process, as depicted in Figure 1. Figure 5 displays the priorities agreed for the Macedon Ranges Shire about where resources should be targeted for future data collection to identify and map significant biological assets. The map concentrates on areas outside existing known biological assets and highlights those areas with (potential) habitat significance, or biological assets under threat from urban development, proximity to townships, and through agricultural and forestry activities.

5.0 Caveats in Relation to the Framework/Model

All models, from a simple 3-D, small replica of a building to a very complex computer-based model of climate change, are representations of reality (Chadwick, 1971). And, in the particular case of vegetation and habitat models, due to the complexity of natural ecosystems, they undoubtedly are simplifications of very complex phenomena. Moreover, models are designed for particular purposes and application at defined geographic scales (Sposito et al, 2001). Specifically, the Regional Habitat Significance Model has been formulated for application at regional and local government levels. It should not be used to deal with some spatial processes (for example, connectivity of vegetation patches) for which the two methods referred to in Section 6, below, are more appropriate. Therefore, care should be taken in its application and the conclusions drawn from it. Some of the main concerns that can be raised in relation to the framework/model are addressed below.

5.1 Integrating Expert Knowledge

Expert knowledge is considered an important resource that may improve the reliability of modelling (Dzerovski et al, 1997; Venterink and Wassen, 1997). It is particularly valuable where no systematic field investigations have been conducted (Maddock and Samways, 2000). Radeloff et al (1999) comment that the incorporation of location-specific knowledge of biologists and other experts is a key to enhancing habitat models, and thus improving wildlife management.

In the model described in this note, a GIS has been used to achieve this as well as help obtain spatially-explicit habitat information from experts. The GIS-based framework effectively provides a virtual environment for experts who are familiar with what exists in the study area. The advantages of using interactive computer-based methods, such as GIS, for acquiring, archiving and analysing expert knowledge are discussed in detail in Wightmann (1995) and Zhu (1999). In a recent study in the Lake Eildon National Park in Victoria, a study was undertaken on eliciting and integrating expert knowledge for wildlife habitat modelling. It was concluded that a GIS-based approach is important as it provides experts with a spatial context in a repeatable, objective and structured framework. It also simplifies data management, analysis and construction of habitat maps (Yamada et al, 2003).

5.2 Error Propagation and Uncertainty

All multi-criteria analyses, such as the analytic hierarchy process, incorporate a range of data sets that have an error component; so errors propagate through the modelling. Most of the research identifies a threefold breakdown of uncertainty types into:

(i) data-derived,

(ii) display derived, and

(iii) modelling-derived errors

(Lowel and Jaton, 1999; Leung, 1997).

Moreover, a fourth type of uncertainty, spatial variation, has also been identified (Hunsaker et al, 2001). There is no known way to combine all of these sources of uncertainty into one, overall estimate of total model accuracy. Nevertheless, Primary Industries Research Victoria has been conducting research in this important area to develop a quantification technique for calculating confident limits around eventual model outputs (Hossain and Wyatt, 2005). The initial study concentrated on the estimation of:

(a) the error in input GIS-based data layers and

(b) the propagation of data errors within a land suitability model which uses the analytic hierarchy process. It has not been applied yet to the framework/model described in this note, but the general conclusions clearly reinforce the susceptibility of this type of method to data quality.

Because of the uncertainty involved, recent approaches to suitability modelling have tended to move away from the traditional hard decisions and have introduced 'soft' conclusions (Eastman, 1999). Other researchers are investigating the application of Bayesian statistics to 'embracing uncertainty' (Anderson, 1998).

Yet, decisions still need to be made on the basis of imperfect model outputs to underpin planning and management of habitats and natural resources.

6.0 Other Relevant Methods

6.1 Habitat Suitability Index

One widely used method for describing the environmental features that are important in determining the distribution and abundance of a species is the *habitat suitability index* modelling. This index for a given species and area of land represents a conceptual model that relates each measurable variable of the environment to the suitability of a site for the species (USFWS, 1980 and 1996; Burgman et al, 2001). The indices are scaled from 0 (for unsuitable habitat) to 1 (for optimum conditions). Each environmental variable is represented by a single suitability index, and when combined, these constitute a habitat suitability index that expresses the suitability of particular habitat for the species in question.

In this model, environmental factors may be assigned weights reflecting the relative importance of different components of the habitat. The construction of the habitat suitability indexes is primarily a process for making a descriptive synthesis of information of the biology and life history of a species in a particular site. This is based on a combination of the available data together with expert opinion on the species' biology (Burgman and Lindemayer, 1998). The paper by Yamada et al (2003) describes the construction of a habitat suitability model for Lake Eildon National Park using this method.

6.2 Habitat Hectares Method

Victoria's Native Vegetation Management – A Framework for Action (Department of Sustainability and Environment, 2002) introduced the concept of the 'Habitat Hectares' method of assessing the quality of stand of native vegetation. This is an explicit, quantitative method that combines site condition and landscape context components to reach an overall assessment of the remnant vegetation. The condition of the vegetation remnant is compared to a benchmark condition that more closely resembles the benchmark standard considered to have higher quality. Site condition components include:

(a) retention of old trees (woodland and forests)

(b) retention of the tree canopy cover (woodlands and forest)

(c) retention of the cover of, and diversity within, understorey life forms

(d) absence of weed species; and

(e) ground litter and the presence of rocks (woodlands and forest).

Landscape context include the size of the remnant vegetation patch and links to, and amount of, neighbouring vegetation patches (Parkes et al, 2003).

Once the site vegetation assessment is completed, the habitat quality is multiplied by the area of the remnant to give the overall 'Habitat Hectare' score. Within the context of the Native Vegetation Management Framework, the score is then use to determine whether clearing of native vegetation should be allowed, as well as which appropriate offset/management actions are required by the landholder.

It should be noted that this method has received scientific criticisms. In particular, it is argued that error increases with the size of the area being assessed, such that errors may be substantial when estimating cover for stands of 20 hectares or more. McCarthy et al (2004), whilst supporting the use of this explicit quantitative approach to assessing habitat quality because it makes the logic behind the assessment transparent and repeatable, offer several suggestions to improve the method.

7.0 Conclusion

The *Vegetation and Habitat Strategic Framework* described in this note provides a strategic understanding of the complex natural environment of a region or local government area. Its construction, as a decision support system in a GIS platform, allows the ongoing improvement of the relevant information and the preparation of a new assessment in an adaptive, cyclical planning process. Its core component, the *Regional Habitat Significance Model* combines both scientific-based information and qualitative expert knowledge. The framework/model must, however, be supported by field investigations at a site level. Thus, the framework also establishes an appropriate context for the application of more detailed methods; for example, the 'habitat suitability index' method or the 'Habitat Hectares' method (with improvements) briefly described above.

The construction flexibility inherent in the framework/model makes possible its application in other regions of Australia. Specifically, the computer program developed by Primary Industries Research Victoria (see footnote 2) enables the rapid construction of a decision-making hierarchy for any area of land. However, the framework has so far been applied in only two regions – Wyndham (Department of Primary Industries, 2004a), and Macedon Ranges (Department of Primary Industries 2004b) in which the description of the method has been based. More importantly, the framework/model requires further testing, modifications and improvements. As mentioned by the distinguished philosopher of science, Karl Popper: 'the critical attitude, the tradition of freer discussion of theories with the aim of discovering their weak spots so that they may be improved upon, is the attitude of reasonableness, or rationality. It makes far reaching use of both verbal arguments and observation – of observation in the interest of argument, however' (Popper, 1965, pp 50–51). This is after all how science advances.

As contended by the author in a previous BDP *EDG* Note (DES 50 – *Sustainability and Urban Containment*), the greatest conflict between physical/economic development and biodiversity conservation is now taking place in all the peri-urban regions of Australia, especially around our metropolises. It is precisely in these peri-urban regions, where the application of ESD principles must guide development. Methods that operationalise Ecologically Sustainable Development, such as those described in this note, should underpin the planning and design of all new developments and therefore be extensively applied by land use and environmental planners, landscape architects, architects and environmental engineers.

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Biography

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Awards

A Strategic Approach to Habitat and Conservation Significance, the framework and methodology outlined in this note and developed/applied in the report *Macedon Ranges - Habitat Quality and Conservation Significance* was awarded the following state and national awards;

1. *Environmental Planning or Conservation – Award for Planning Excellence* (2004) Planning Institute of Australia (Victorian Division);
2. *Planning Scholarship or Teaching – Certificate of Commendation for Planning Excellence* (2004) Planning Institute of Australia (Victorian Division); and
3. *Environmental Planning or Conservation – Merit National Award for Planning Excellence* (2005) Planning Institute of Australia.

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